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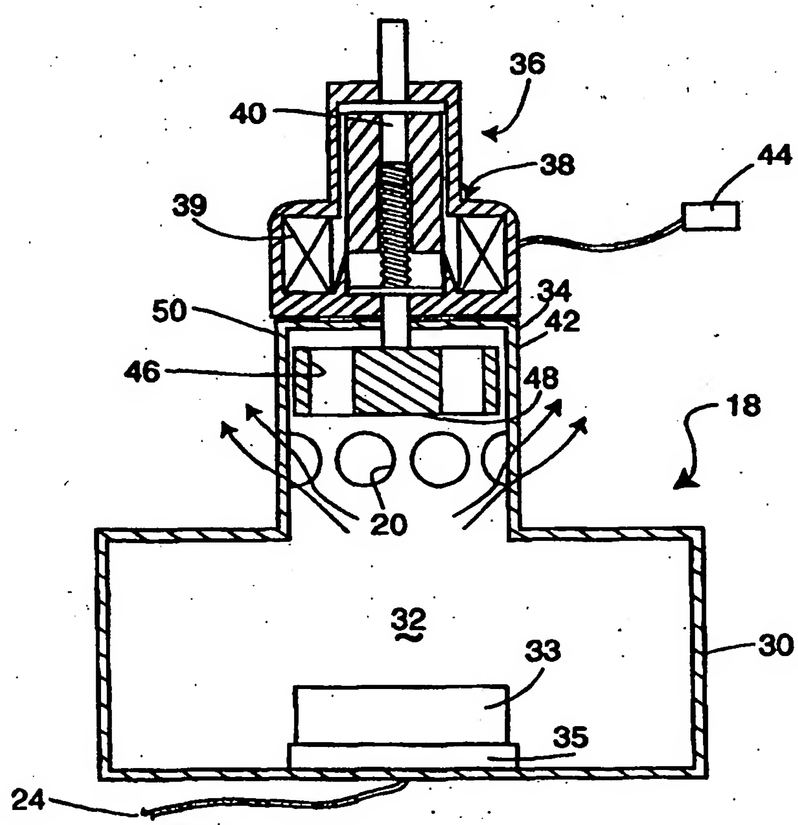
(54) Title: EXHAUST REGULATORS FOR AIRBAG INFLATOR SYSTEMS

(57) Abstract

An airbag deployment system (10) includes an airbag (12) and an airbag inflator (18) that can be activated by a crash management controller for generating inflation gas that is discharged through one or more exhaust ports (20) to inflate the airbag. The system further includes an exhaust regulator device (36) that is selectively activated by the crash management controller for regulating the flow of the inflation gas through the exhaust ports and adaptively changing the deployment rate of the airbag. The exhaust regulator device includes a valve (42) that is movable relative to the exhaust ports for varying the orifice size through which the inflation gas is discharged.



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EXHAUST REGULATORS FOR AIRBAG INFLATOR SYSTEMS

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates generally to an airbag system having an airbag inflator equipped with an exhaust regulator for adaptively controlling inflation of an airbag.

Safety restraint systems are used in motor vehicles for protecting the vehicle occupants during collisions. In addition to seat belts, many safety restraint systems now include a driver side airbag mounted in the steering wheel and a passenger-side airbag mounted in the dashboard. Furthermore, recent attention has been directed to incorporation of other restraint devices such as, for example, side airbags, seat belt pretensioners, and energy management retractors into the safety restraint system. Many, if not all, of these restraint devices are activated by the vehicle's crash management system in response to detection of a vehicular collision exceeding a predetermined impact magnitude.

Many airbag and safety restraint devices are deployed in response to activation of an inflator by the vehicle's crash management system. Typically, activation of the inflator generates a predetermined output, based on the magnitude of gas or propellant discharge, for deploying its associated airbag or safety restraint device. To optimize occupant protection during a collision, it is desirable to vary the deployment characteristics of the airbags and/or the operational characteristic of the other restraint

devices based on various control parameters such as, for example, the severity of the crash, belt usage, the position, size and/or weight of the seat occupant, seat position, and ambient temperature. Thus, the vehicle's crash management system includes various sensors for detecting and/or measuring such control parameters and a controller for adaptively varying the inflator output in response to the sensor signals.

One method for regulating the output of an inflator is through the use of an inflator having two or more separate stored energy devices, commonly referred to as a multi-level inflator. These stored energy devices may be a quantity of combustible pyrotechnic material, gas or liquid and an associated igniter or squib which initiates the burning of the combustible material. Typically, such multi-level inflators include a first stored energy device (interchangeably referred to as a quantity of pyrotechnic material), and a slightly larger second stored energy device (also interchangeably referred to as a quantity of pyrotechnic material), each of which can each be independently activated. In response to a relatively minor crash, only the first stored energy device is activated. Likewise, in a more severe crash, only the second stored energy device is activated. However, in a high severity crash, both stored energy devices are simultaneously activated for providing maximum inflator output. Multi-level inflators can alternatively be used for regulating inflator output in response to the size, weight, position, etc., of the vehicle occupant, if used in conjunction with the appropriate occupant detection sensors. However, multi-level inflators are expensive

to manufacture because of the need to integrate two separate quantities of pyrotechnic material and initiators or squib devices into a single inflator unit. Moreover, even if only one of the stored energy devices is discharged, the entire inflator unit must still be replaced.

In view of these systems, it is desirable to provide a lower cost system for regulating the output generated by the inflator. One such approach is to provide a single inflator having an exhaust-regulating device for selectively regulating the inflator output and adaptively controlling the deployment force provided to the safety restraint device.

Accordingly, the present invention is directed to a system for regulating the rate at which an airbag is inflated, or at which other safety restraint devices are deployed by controllably regulating the output generated by the inflator. This objective may be achieved by incorporating an exhaust regulator device into a single level inflator.

As part of the present invention, an airbag module is equipped with an airbag inflator having a variable flow valve. The regulated inflator includes a housing defining a stored energy or combustible material chamber and at least one exhaust port through which the high-pressure gas produced by the inflator is directed outside the inflator. The variable flow valve is operable for selectively varying the orifice size of the exhaust port or ports, thereby modifying the inflation gas discharge rate of the inflator. The variable flow valve includes a valve member that can be moved with respect to the exhaust port between first and second positions in response to controlled

activation of an electrical actuator for regulating the inflation gas discharge rate between a maximum level and a minimum level.

BRIEF DESCRIPTION OF THE DRAWINGS

The various advantages of the present invention will become apparent to one skilled in the art by reading the following specification and appended claims, and by referencing the following drawings in which:

FIG. 1 is an exploded perspective view of an exemplary airbag module for use in accordance with the preferred embodiments of the present invention;

FIG. 2a is a partial sectional view of an airbag inflator adapted for use with the airbag module and having a variable flow valve shown in a non-actuated state;

FIG. 2b shows the inflator of FIG. 2a with the variable flow valve in an actuated state;

FIG. 3 is a sectional view taken generally along line 3-3 of FIG. 2b;

FIG. 4a is a partial sectional view of the inflator having an alternative variable flow valve shown in a non-actuated state;

FIG. 4b shows the inflator of FIG. 4a with the alternative variable flow valve in an actuated state;

FIGS. 5 and 6 are top plan views of valve members adapted for use with the variable flow valve shown in FIGS. 4a and 4b;

FIGS. 7a and 7b are partial sectional views of an inflator equipped with a variable flow valve constructed according to an alternative embodiment;

FIG. 8 is a partial sectional view of an inflator equipped with a variable flow valve according to another alternative embodiment of the present invention;

FIG. 9 is a perspective view of the valve member shown in FIG. 8;

FIG. 10 is a partial sectional view of the inflator having an alternative variable flow valve;

FIG. 11 is a perspective view of the valve member shown in FIG. 10;

FIG. 12a is a partial sectional view of an inflator and variable flow valve according to an alternative embodiment of the present invention;

FIG. 12b is a sectional view taken generally along line 12b—12b of FIG. 12a;

FIG. 12c is a sectional view showing the alternate variable flow valve in one of several positions;

FIG. 13a is a partial sectional view of the inflator having an alternative variable flow valve;

FIG. 13b is a sectional view taken generally along line 13b–13b of FIG. 13A;

FIG. 13c is a top view of the flow restrictor valve member shown in FIG. 13a; and

FIG. 14 is a schematic showing the crash management controller for controlling a driver and passenger safety restraint system.

DETAILED DESCRIPTION OF THE INVENTION

In general, the present invention is directed to an inflator that employs an exhaust-regulating device for adaptively controlling the inflator output. While the following description is directed to the use of an inflator in an airbag restraint system, it will be understood that the present invention is also applicable to adaptively controlling the output of any gas producing device used in association with the activation of other types of safety restraint devices.

With reference to FIG. 1, an exemplary airbag module assembly 10 is shown. Airbag module assembly 10 includes an airbag 12 (shown in its folded configuration), an optional airbag mounting ring or plate 14, an optional manifold 16 having a plurality of distribution ports 17, an inflator 18 having one or more exhaust ports 20, and a housing or reaction canister 22. The inflator 18 can be inserted within manifold 16, if used, and the assembly is then secured within reaction canister 22. The mounting ring 14, if used, is fastened to the open, front face of reaction canister 22. As is conventional, one or more quantities of pyrotechnic material is secured within inflator 18 and has an igniter, squib, or an equivalent device, in electrical communication with the vehicle's crash management controller (CMC) 26 such as via wiring harness connector assembly 24. When the vehicle's on-board crash detection sensor(s) 28 detect a crash scenario, the CMC 26 sends an electric control signal to the igniter to activate inflator 18 for generating a high pressure gas which is directed through exhaust ports 20 and distribution

ports 17 to inflate airbag 12. The flow rate of the gas discharged through exhaust ports 20 can be regulated using a flow valve 36 (described in greater detail below) which is connected to CMC 26 via an electrical connector 44. As is also known in the art, airbag 12 can be secured directly to manifold 16 or to inflator 18 in which case airbag 12 would reside within the body of reaction canister 22. The mounting scheme will typically depend upon the type of inflator and housing used. While not shown, a deployment cover is typically used to enclose reaction canister 22 and protect airbag 12.

Referring now to FIGS. 2a and 2b, a portion of inflator 18 is shown to include a cylindrical housing 30 which defines a stored energy or pressure chamber 32. As is known in the art if the chamber 32 may be filled with an inert gas, or a combustible gas or liquid, or solid propellant, such as propellant 33. The ignition of propellant 33 is achieved through squib or initiator device 35 that is controlled by CMC 26 via wiring harness 24. An end portion 34 of housing 30 communicates with chamber 32 and has exhaust ports 20 formed circumferentially therein. In accordance with the present invention, an exhaust regulator or regulating device, hereinafter referred to as flow valve 36, is associated with inflator 18 for regulating the rate (i.e., the inflation rate) at which the pressurized gas is discharged through exhaust ports 20 in response to activation of inflator 18. Flow valve 36 includes an electrically activated solenoid or actuator 38 having a coil 39 and a plunger assembly 40 supported for axial movement in response to an electric control signal sent to actuator 38 from

the vehicle's crash management controller (CMC) 26, for controlling the position of a valve member 42. The valve member 42 is fixed to the distal end of plunger assembly 40 within end portion 34 such that movement of plunger assembly 40 causes corresponding axial movement of valve member 42. Actuator 38 may be a solenoid, an electromagnet, a stepper motor, or a pyrotechnic pin puller or pusher (having an open and closed position) which is operable for controlling the position of valve member 42 relative to exhaust ports 20. A harness and connector assembly 44 as shown in FIG. 1 provides an electrical connection between actuator 38 and CMC 26. It is preferable that the actuator 38 is activated prior to energizing the squib or initiator device 35 that controls the generation or production of inflation gas produced by propellant 33. This would reduce the required axial force to move and maintain plunger assembly 40 and valve member 42 in the desired position by actuator 38 since there would be no inflation gas pressure acting on valve member 42.

With continued reference to both FIGS. 2a and 2b, the function of regulated airbag inflator 18 is disclosed. In operation, actuator 38 controls the position of valve member 42 (in correspondence with occupant and accident parameters programmed into CMC 26) for selectively changing the orifice size of exhaust ports 20, thereby changing the flow rate of the pressurized gas discharged through exhaust ports 20. Thus, the interaction of valve member 42 with exhaust ports 20 provides the variable inflator output characteristic of the present invention. In FIG. 2a, flow valve 36 is shown in a "non-actuated" state with

valve member 42 retracted to a first position for permitting uninhibited flow of the inflation gas through exhaust ports 20. Typically, CMC 26 signals actuator 38 to maintain valve member 42 in its first position when it is determined that a maximum deployment rate is required. In contrast, FIG. 2b illustrates flow valve 36 in a "fully-actuated" state with valve member 42 extended to a second position whereat it limits flow of the inflation gas through exhaust ports 20. In operation, CMC 26 signals actuator 38 to move valve member 42 to its second position when it is determined that a minimum deployment rate is required. Upon actuation of the flow valve 36, the inflation gas, as represented by the arrows, is discharged through the orifices defined between valve member 42 and exhaust ports 20. Additionally, some of the gas flows through optional by-pass vents 46 (FIG. 3) formed through valve member 42 and which serve to equalize the gas pressure acting on opposite face surfaces 48 and 50 of valve member 42. Vents 46 are desirable in that equalization of pressure on opposite sides of valve member 42 permits use of smaller actuators 38 since the axial output force required to move and maintain valve member 42 in its desired position is reduced. Actuator 38 may also be used for moving the flow valve 36 into various intermediate positions, as well as controlling the duty cycle or movement of flow valve 36 for controlling the "effective" open area of the valve.

In a typical crash scenario, the vehicle's crash management controller 26 determines the severity of the impact, and activates the appropriate safety restraint devices. When the crash management

controller 26 determines that the deployment force of one or more of the adaptive airbags must be modified in accordance with the severity of the crash, the seating position of the occupant (that is if the occupant is in a normally seated position or out of position), the size or weight of the occupant, the seat position, the ambient temperature, or the presence of a child safety seat, controller 26 may selectively activate flow valve 36 for adaptively changing the deployment rate provided during airbag inflation. More specifically, this involves providing controller 26 with the means to generate and send a variable electrical control signal to actuator 38. By regulating the electrical control signal sent to actuator 38, valve member 42 can be positioned anywhere between its first and second positions. As such, the size of the orifice through exhaust ports 20 can be changed, thereby controlling the output generated by inflator 18 and subsequently communicated to airbag 12. For example, when controller 26 determines from sensors 28 that the vehicle occupant is small and/or the occurrence of a minor impact force, flow valve 36 is shifted into its fully actuated state for reducing the deployment rate of airbag 12. Alternatively, in a severe crash situation, or if a larger vehicle occupant is detected, controller 26 will maintain flow valve 36 in its non-actuated state for providing maximum airbag deployment rate. Thus, information regarding predetermined flow characteristic through exhaust ports 20 based on the size of exhaust ports 20 and the position of valve member 42 is stored in controller 26.

and used for determining the magnitude of the electrical control signal sent to actuator 38.

As an alternative, inflator 18 may be used for driving multiple safety restraint devices through a manifold network 37 such as is shown in FIG. 14. As such, if crash management controller 26 activates a single airbag 12, a lower amount of energy would be required from inflator 18 by actuating one of the flow restrictor valves 36. However, if multiple airbags 12 are to be driven by a single inflator 18 during a crash, crash management controller 26 can maximize the output of inflator 18 by maintaining valve member 42 associated with each flow restrictor valve 36 in the fully open position. Additionally, one skilled in the art will appreciate that other scenarios exist in which the output from inflator 18 could be regulated, and that valve member 42 may take on an infinite number of positions between the first and second positions.

Turning now to FIGS. 4a and 4b, regulated airbag inflator 18 is shown in association with an alternate construction for valve member 42. While the modification affects the general shape of valve member 42, the operation of regulated inflator 18 is substantially similar to that described above. As shown in FIG. 4a, valve member 42a is cup-shaped and includes a circular disc 52 and a cylindrical sidewall 54. Circular disc 52 is secured to plunger assembly 40 and cylindrical side wall 54 operates to vary the orifice size of exhaust ports 20 when actuator 38 moves valve member 42a from its first position (FIG. 4a) toward its second position (FIG. 4b). As shown in FIG. 4b, valve member 42a may optionally include a

plurality of apertures 56 formed through disc 52. As such, apertures 56 allow the inflator gas to circulate above circular disc 52 for equalizing the pressure differential between opposing surfaces of valve member 42a. Apertures 56 in valve member 42a can be defined by a series of circumferentially aligned holes. As an alternative, a valve member 42b is shown in FIG. 5 with a pair of contoured cutouts 60 formed in disc 52 that also provide for pressure equalization. As a further alternative, FIG. 6 illustrates a valve member 42c having quadrant-shaped cutouts 62 formed in disc 52.

A further advantage of valve members 42a, 42b, and 42c is equalized gas pressure around the inner circumference of cylindrical sidewall 54. The inflation gas pressure causes the valve member to expand radially. This results in the outer surface of cylindrical sidewall 54 coming into contact with the inner surface of end portion 34. This press fit condition prevents any axial or rotational movement of the valve member during the inflation gas discharge event. The actuator then has to provide no resistive axial force to maintain the valve member in the desired position.

Turning now to FIG. 12a, regulated airbag inflator 18 is shown in association with an alternate construction for valve member 42. While the modification affects the general shape of valve member 42, the operation of regulated inflator 18 is substantially similar to that described above. As shown in FIG. 12, alternate flow valve member 42d moves horizontally rather than vertically. Valve 42d is secured to plunger assembly 40 and operates to vary

the orifice size of orifices 21 when actuator 38 moves valve member 42d from its first position (FIG. 12b) toward its second position (FIG. 12c). The movement of valve 42d can be a single step motion or a rapid oscillation between the first and second position generally at a cycling rate of at least 1000 Hz. In this embodiment orifices 21 are located at the interface of chamber 32 and end portion 34. As shown, flow valve member 42d includes three fluted channels 43 formed about the circumference thereof. As such, when fluted channels 43 are directly aligned with orifices 21 (FIG. 12c), pressurized gas flow through orifices 21 and exhaust ports 20 is maximized. Alternatively, when the non-fluted portions 45 are directly aligned with orifices 21 (FIG. 12b), pressurized gas flows through orifices 21 and exhaust ports 20 is minimized.

Turning now to FIGS. 7a and 7b, an alternate embodiment of the inflator 18 according to the present invention is shown. More specifically, a flow valve 64 is shown to include a housing 66 and a cup-shaped valve member 68 supported in housing 66 for movement between a first position (FIG. 7a) and a second position (FIG. 7b). Housing 66 is part of an actuator 70 that has a movable plunger 72 coupled to valve member 68. As will be appreciated, actuator 70 is an electrically controlled device that is substantially similar in function to actuator 38; that is, it causes controlled axial movement of valve member 68. Thus, valve member 68 is concentrically mounted to slide axially relative to an exterior surface of housing end portion 34 for controlling the exhaust of the inflator gas through exhaust ports 20. As such, when valve

member 68 is in its first position (FIG. 7a), the orifice size of exhaust ports 20 is maximized. However, movement of valve member 68 downwardly to partially block exhaust ports 20 (FIG. 7b) reduces the orifice size of exhaust ports 20 for regulating the output of inflator 18. Optional by-pass vents can also be provided in valve member 68 if desired.

Referring now to FIGS. 8 and 9, another variation on the regulated airbag inflator 18 is disclosed. In general, a flow valve 74 is schematically shown to include a rotary actuator 76 and an annular valve member or ring 78 concentrically supported on housing end portion 34 for rotation relative thereto. Ring 78 is coupled to a rotary output member of actuator 76, schematically shown by lead line 82. In this embodiment, ring 78 includes a plurality of radial apertures 80 formed through its sidewall which are alignable with exhaust ports 20. A perspective view of ring 78 is shown in FIG. 9 that discloses the spacing of apertures 80 in more particular detail. The rotated position of ring 78 with respect to exhaust ports 20 is controlled by actuator 76. In operation, ring 78 is rotated for altering the alignment, and thus the orifice size, between apertures 80 and exhaust ports 20. Preferably, the circumferential spacing of apertures 80 in ring 78 is complementary to the spacing of exhaust ports 20. Thus, ring 78 can be located in a first position whereat apertures 80 are concentrically aligned with exhaust ports 20 for maximizing the flow rate. The output of regulated airbag inflator 18 can be regulated by selectively rotating ring 78 from the first position toward a second position for reducing

the orifice size, thereby minimizing the flow rate of the inflator gas discharged through exhaust ports 20. Accordingly, the amount of deployment force provided by inflator can be regulated by crash management controller 26 by adaptively changing the rotated position of the ring 78.

Referring now to FIGS. 10 and 11, another variation on the regulated airbag inflator 18 is disclosed. In general, a flow valve 74 is schematically shown to include a rotary actuator 76 and an annular valve member or ring 78 concentrically supported inside housing end portion 34 for rotation relative thereto. Ring 78 is coupled to a rotary output member of actuator 76 by a shaft 79. In this embodiment, ring 78 includes a plurality of radial apertures 80 formed through its sidewall which are alignable with exhaust ports 20. A perspective view of ring 78 is shown in FIG. 11 that discloses the spacing of apertures 80 in more particular detail. The rotated position of ring 78 with respect to exhaust ports 20 is controlled by the actuator 76. In operation, ring 78 is rotated for altering the alignment, and thus the orifice size, between apertures 80 and exhaust ports 20. Preferably, the circumferential spacing of apertures 80 in ring 78 is complementary to the spacing of exhaust ports 20. Thus, ring 78 can be located in a first position where apertures 80 are concentrically aligned with exhaust ports 20 for maximizing the flow rate. The output of regulated airbag inflator 18 can be regulated by selectively rotating ring 78 from the first position toward a second position for reducing the orifice size, thereby minimizing the flow rate of the inflator

gas discharged through exhaust ports 20. Accordingly, the amount of deployment force provided by inflator 18 can be regulated by crash management controller 26 by adaptively changing the rotated position of the ring 78. A further advantage of supporting ring 78 within housing end portion 34 is the equalization of gas pressure around the inner circumference of ring 78. The gas pressure causes the ring 78 to expand radially. This results in the outer circumference of ring 78 to come into contact with the inner surface of housing end portion 34. This press fit condition prevents any axial or rotation movement of ring 78 during the inflation gas discharge event. The actuator then has to provide no resistive force to maintain the valve member in the desired position.

Turning now to FIGS. 13a, 13b, and 13c, an alternate embodiment of the inflator 18 according to the present invention is shown. More specifically, flow valve 36 includes a rotatable valve member 100 that is shown to include two propeller blades 105 and two beams 110 of square, rectangular, or circular cross section. Propeller blades 105 and beams 110 are attached to a shaft 115. Shaft 115 is free to rotate about its central axis on a bearing attachment 102. During a deployment event, inflation gas will travel from the stored energy chamber 32 to the end portion 34. As the inflation gas passes over the propeller blades 105, the shaft 115 will have a tendency to rotate. If the actuator 38 remains in the non-actuated state, the shaft 115 will rotate in the direction of the arrows shown in Fig. 13b. Shaft 115 will continue to rotate until the free ends 120 of the two beams 110 contact the mechanical stops 130 built

into the inner surface of end portion 34. A portion of the cross section of the free ends 120 will overlap a portion of the exhaust ports 20 and thereby restrict the flow of inflation gas out of exhaust ports 20. In this embodiment the actuator is offset from the central axis of end portion 34. If actuator 38 is in a fully actuated state during a deployment event, the plunger assembly 40 will move axially (downwardly) into the slot 125 located in the top surface of shaft 115 (FIG. 13c). As a result the rotation of shaft 115 will terminate before the free ends 120 overlap exhaust ports 20. This permits uninhibited flow of the inflation gas through exhaust ports 20 for maximizing the flow of pressurized gas through exhaust ports 20.

CLAIMS

1. An airbag deployment system (10) comprising:

an airbag inflator (18) adapted for fluid communication with an airbag (12), the airbag inflator supplying inflation gas to inflate the airbag (12); and

an exhaust regulator (36) for regulating the flow of the inflation gas through an exhaust port (20) of the airbag inflator, the exhaust regulator (36) being capable of varying the orifice size of the exhaust port (20) through which the inflation gas is discharged and adaptively changing the rate at which inflation gas is discharged from the inflator.

2. The airbag deployment system of Claim 1 wherein the exhaust regulator (36) is a flow valve having an electrically activated actuator (38) and a valve member (42) coupled to a movable output member (40) of the actuator (38), the valve member (42) is movable with respect to the exhaust port (20) between at least first and second positions in response to activation of the actuator (38) for regulating the inflation gas discharge rate between a maximum level and a minimum level.

3. The airbag deployment system of Claim 2 wherein the valve member (42) moves axially relative to the exhaust port (20) to vary the size of the orifice defined therebetween.

4. The airbag deployment system of Claim 2 wherein the valve member (78) is rotated by the

actuator (74) between at least first and second positions for changing the size of the orifice defined between the exhaust port (20) and an aperture (80) formed in the valve member (78).

5. The airbag deployment system of Claim 4 wherein the valve member (78) is an annular ring having a plurality of apertures (80) formed about a circumference thereof.

6. The airbag deployment system of Claim 5 wherein the valve member (78) is supported for rotatable movement on an external surface of an end portion (34) of the airbag inflator (18).

7. The airbag deployment system of Claim 5 wherein the valve member (78) is supported for rotatable movement within an interior chamber of an end portion (34) of the airbag inflator (18).

8. The airbag deployment system of Claim 2 wherein the valve member (42) includes by-pass vents (46) for permitting a portion of the inflation gas to equalize the pressure acting on opposite sides of the valve member (42).

9. The airbag deployment system of Claim 2 wherein the valve member (42d) includes a plurality of fluted channels (43) formed about the circumference thereof.

10. The airbag deployment system of Claim 2 wherein the actuator (38) includes an electrical

connection means (44) for providing electrical communication with a crash management controller (26).

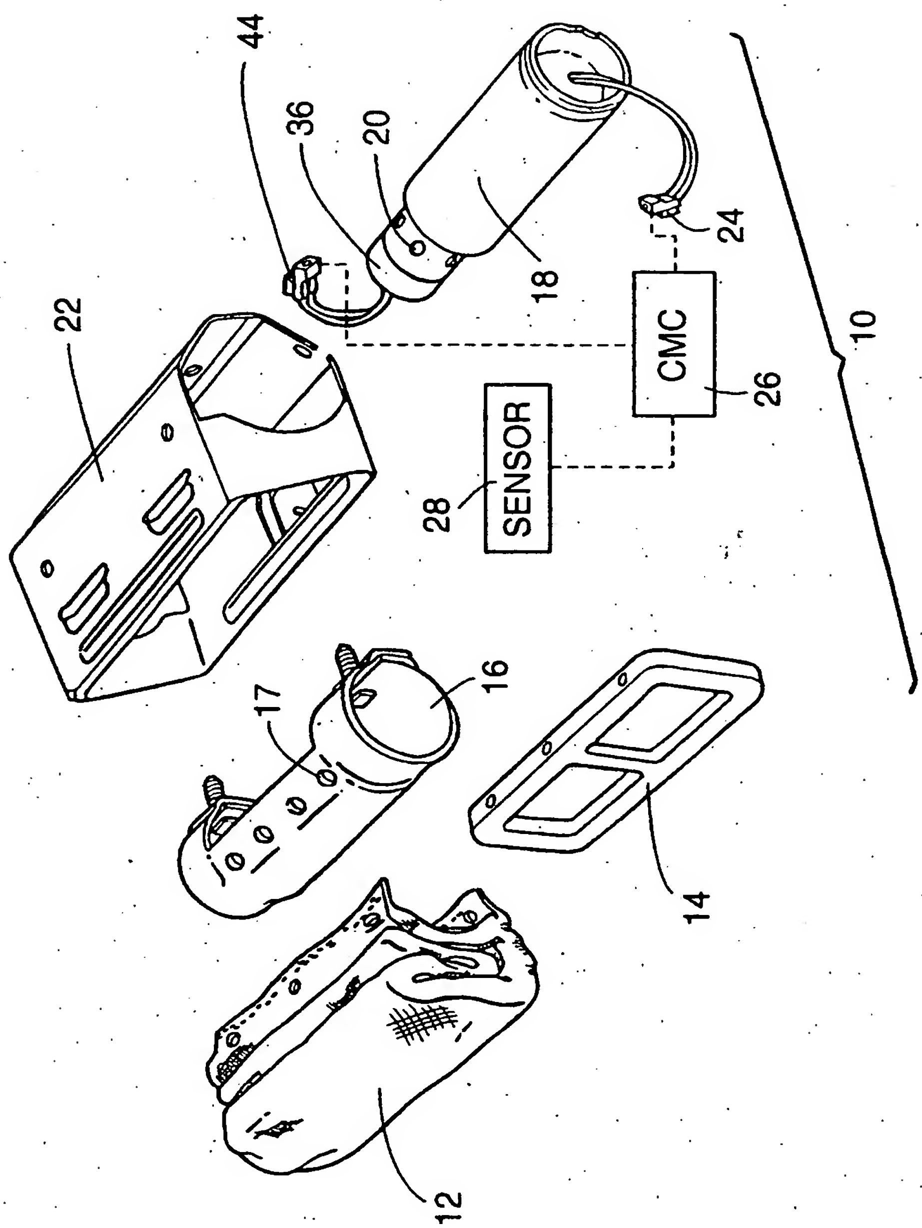

Fig. 1

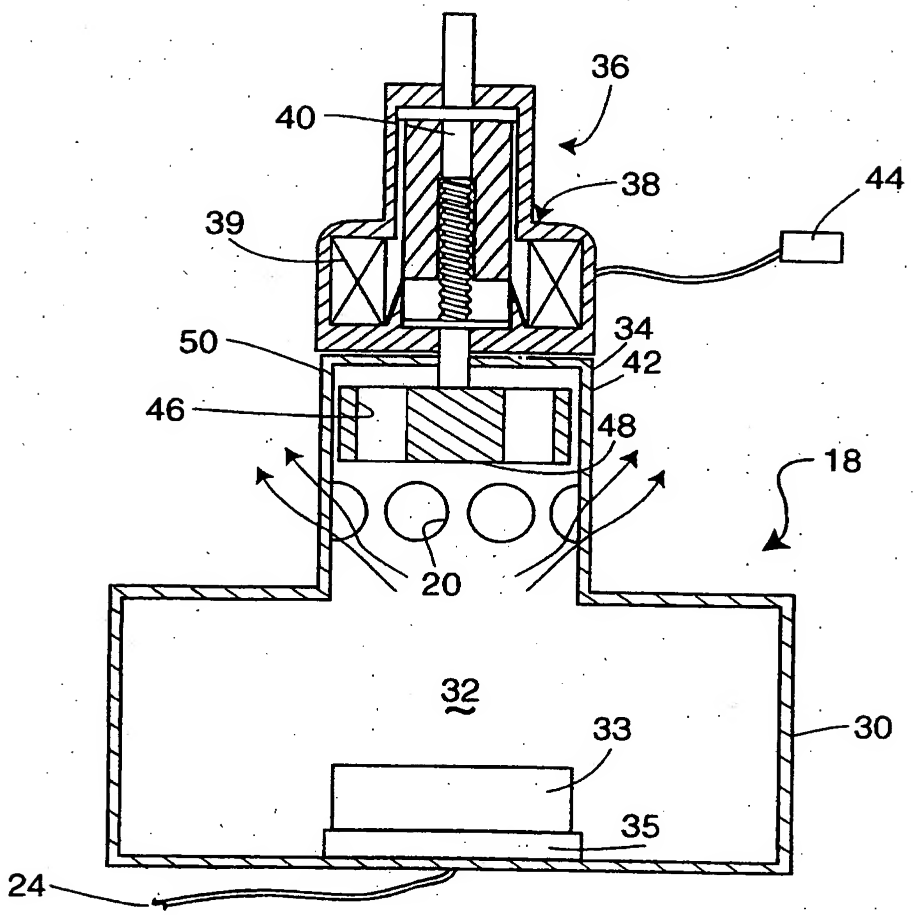

Fig. 2a

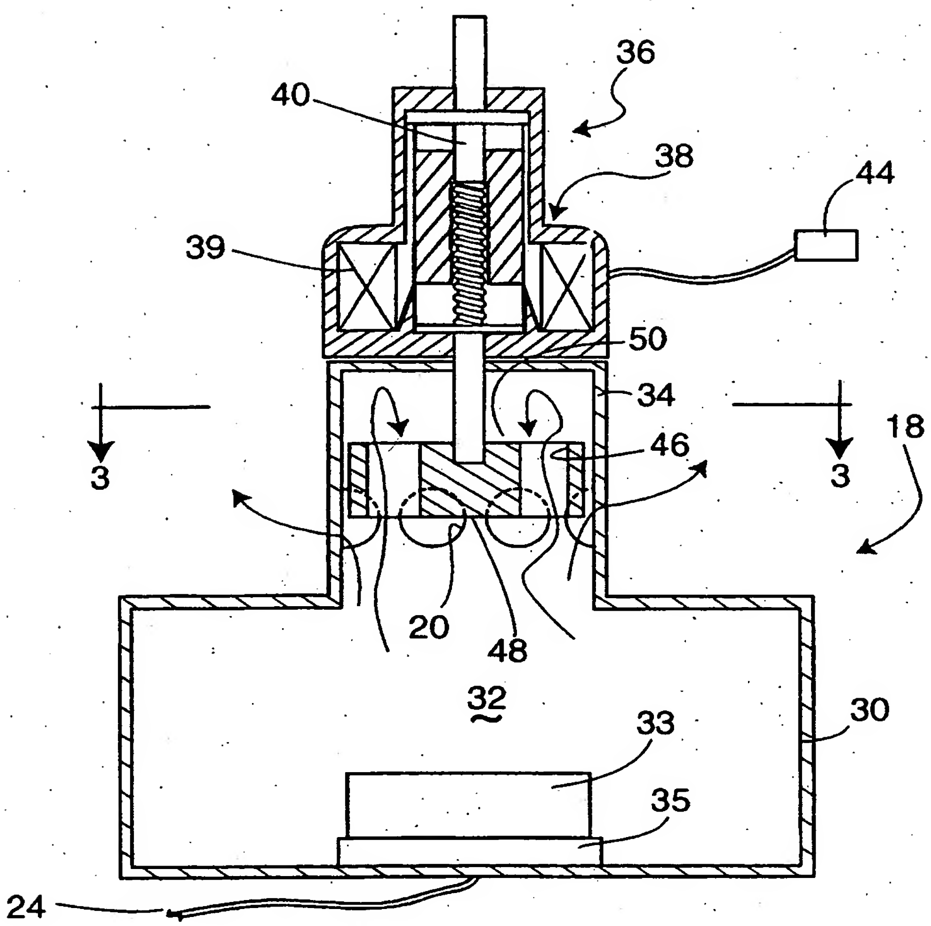

Fig. 2b

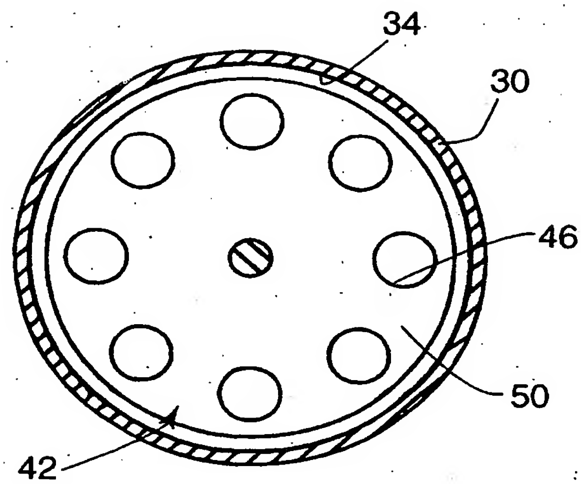

Fig. 3

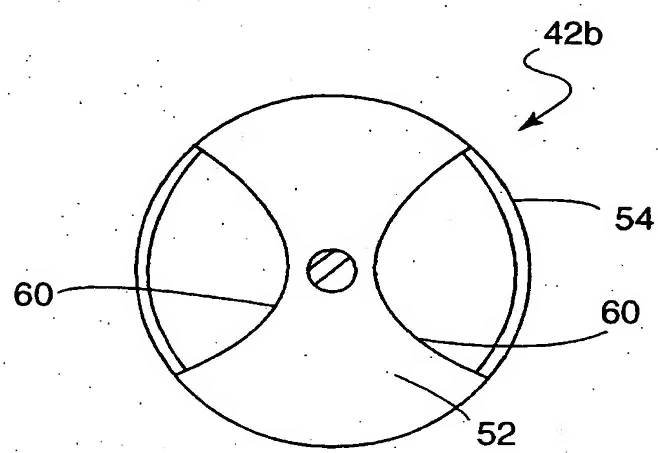

Fig. 5

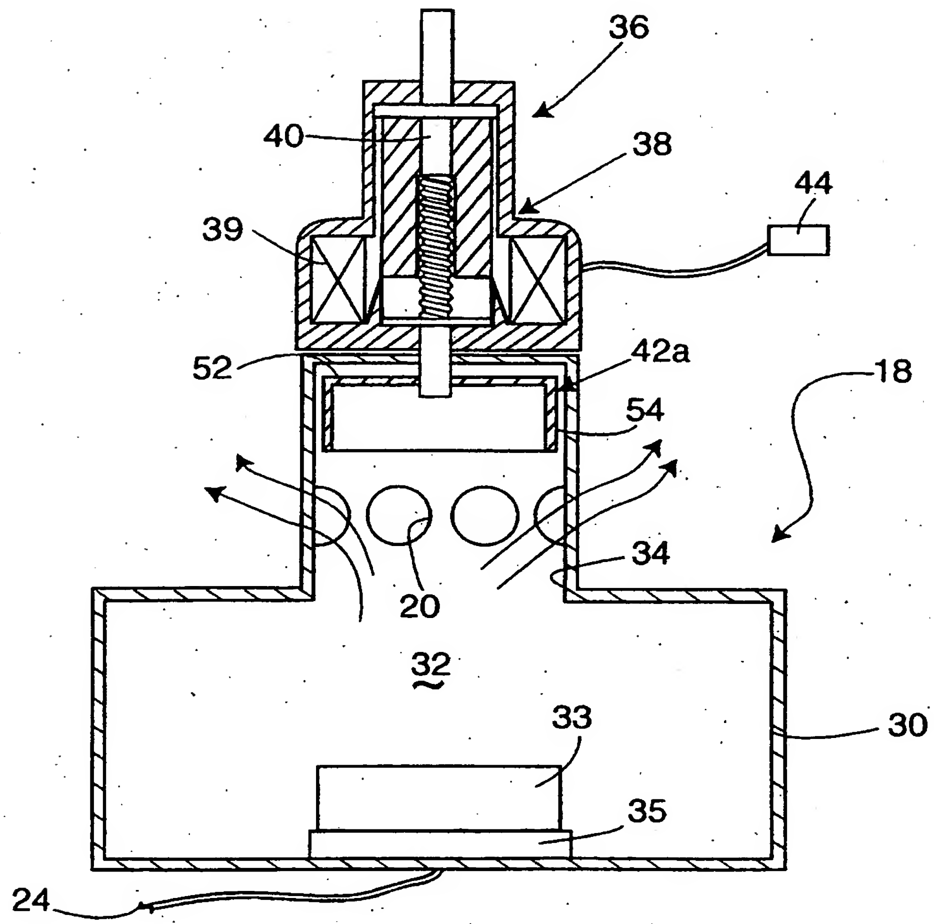

Fig. 4a

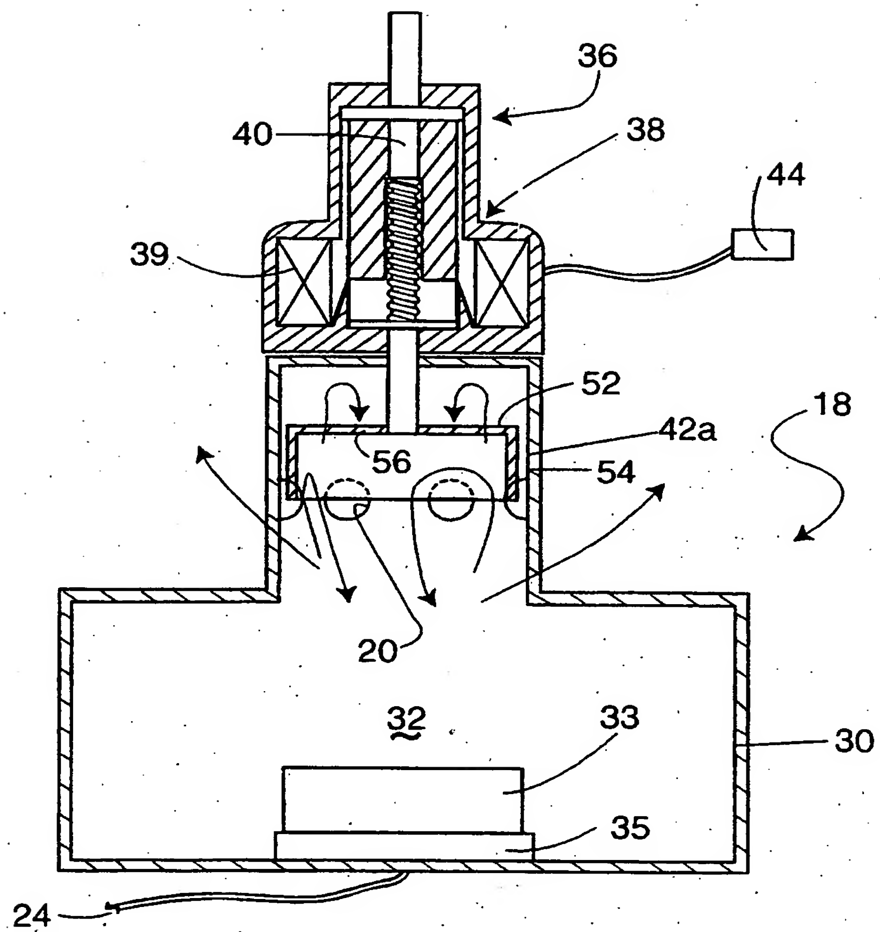

Fig. 4b

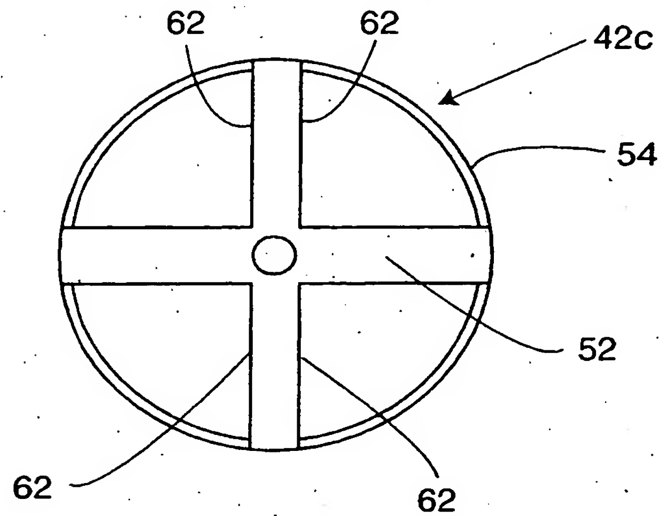

Fig. 6

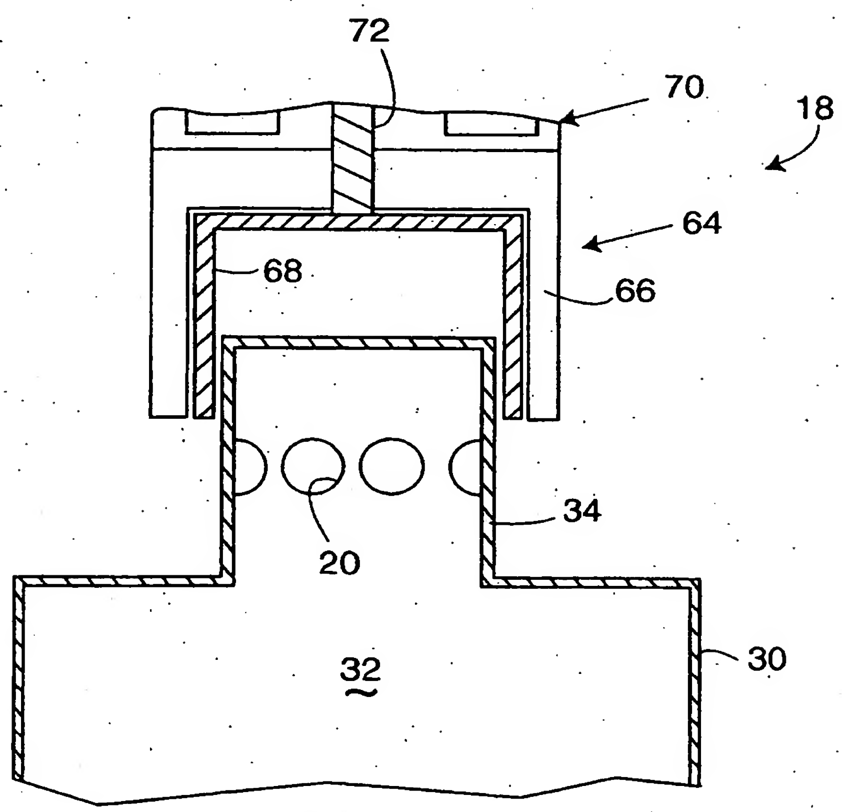

Fig. 7a

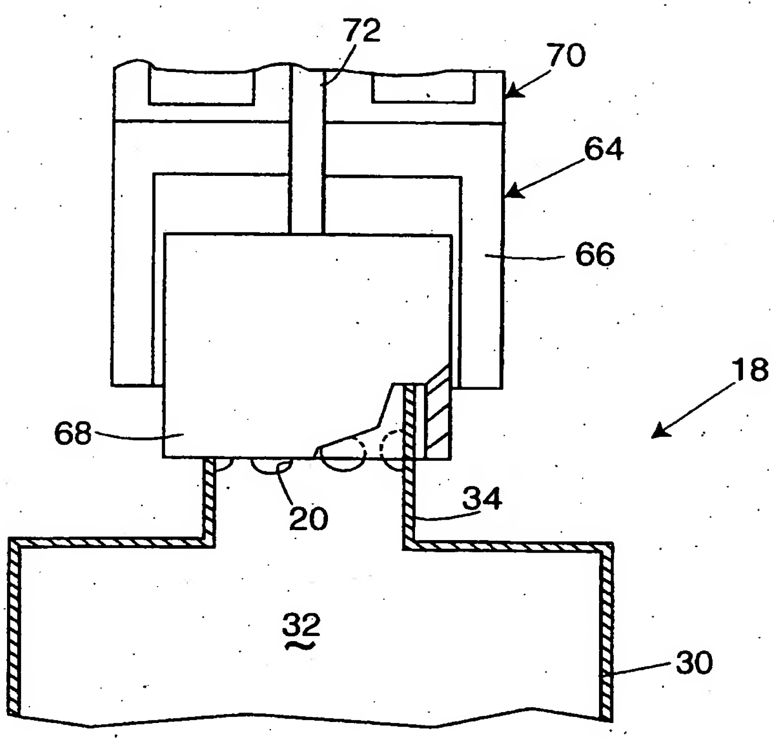

Fig. 7b

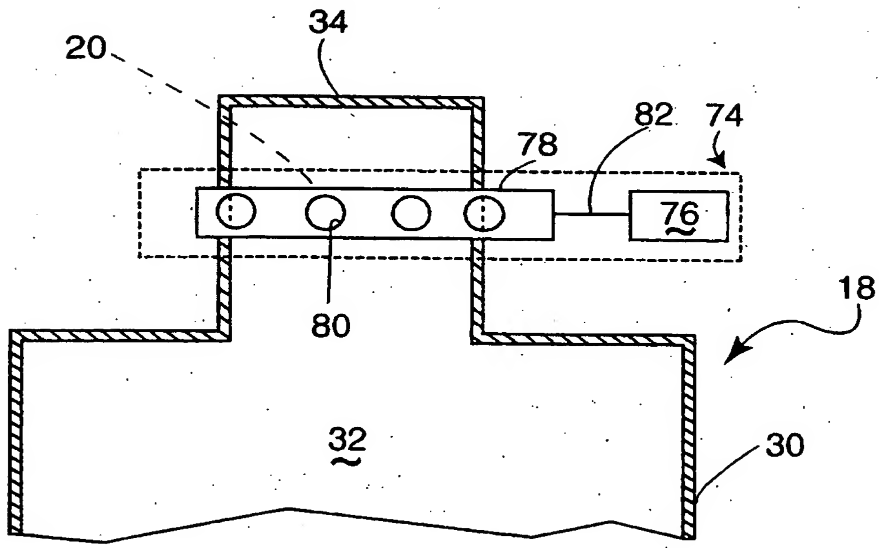

Fig. 8

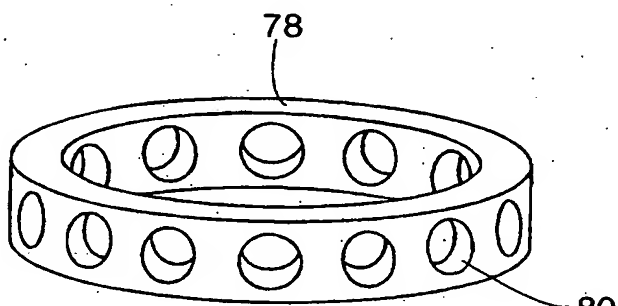

Fig. 9

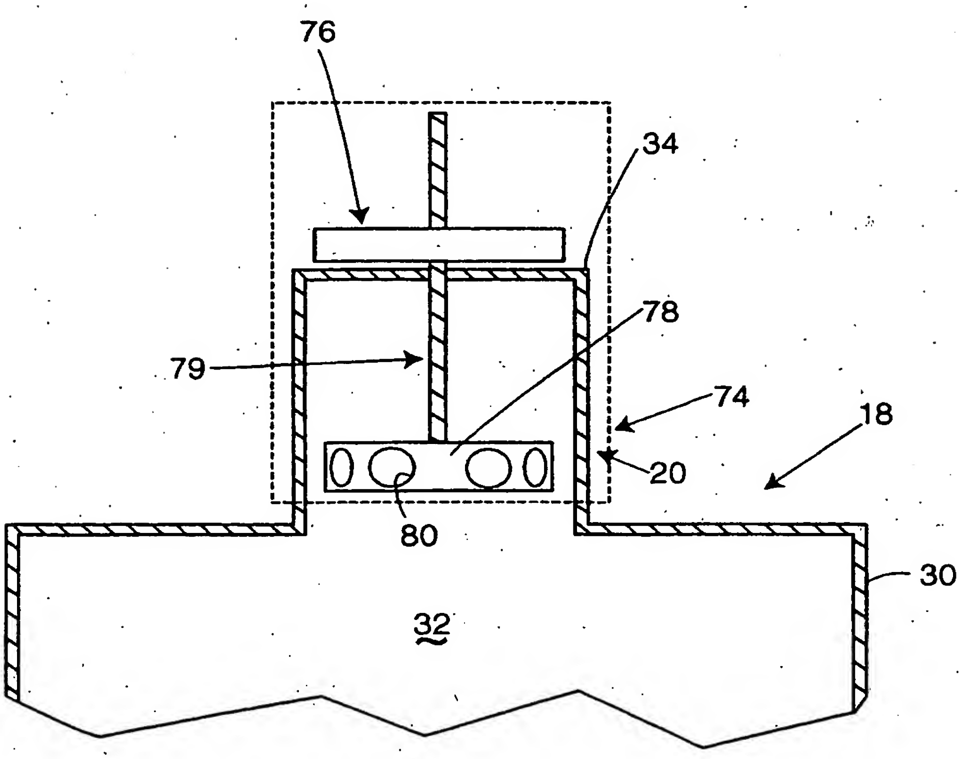

Fig. 10

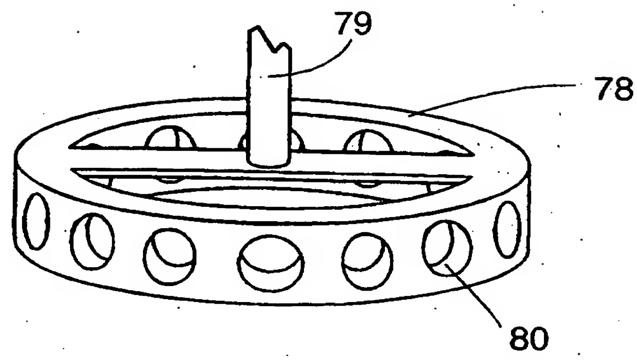

Fig. 11

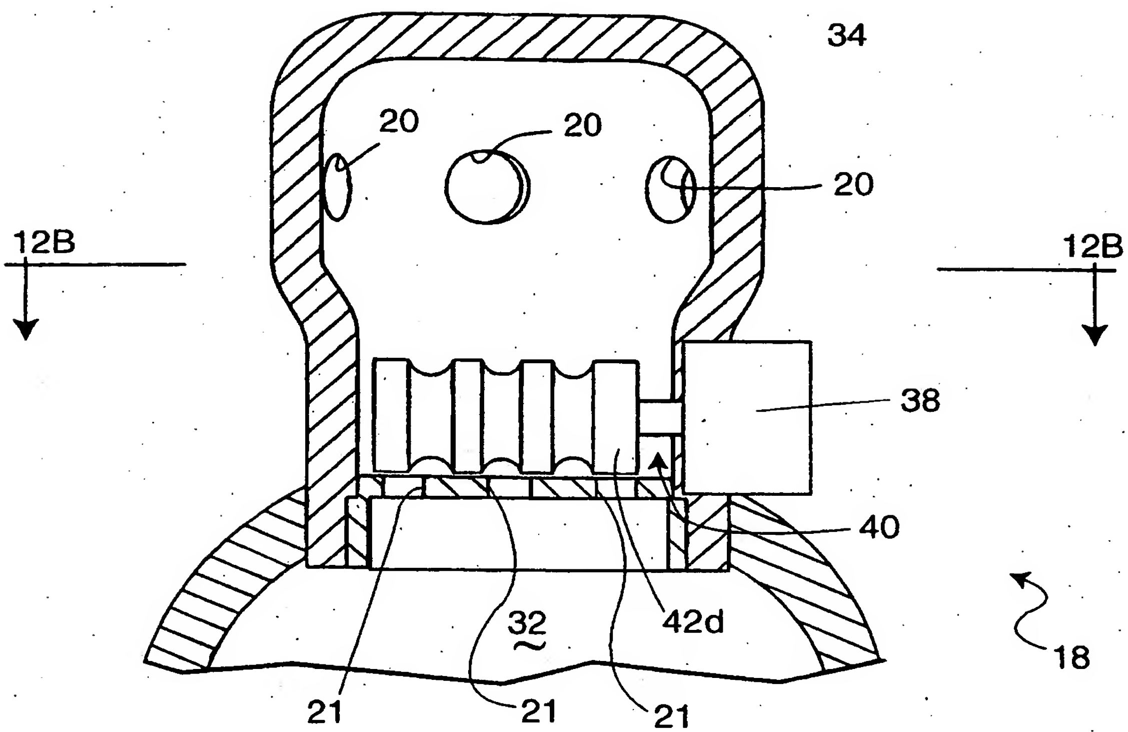

Fig. 12a

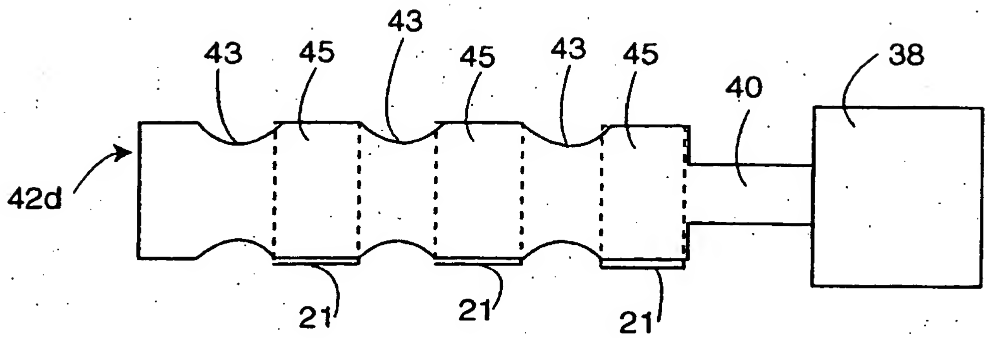

Fig. 12b

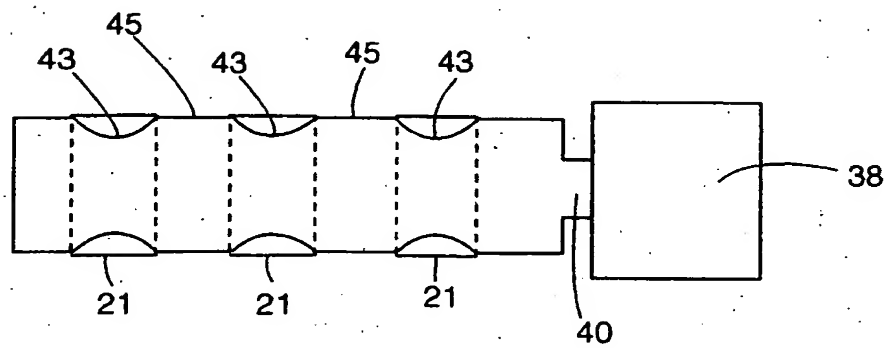

Fig. 12c

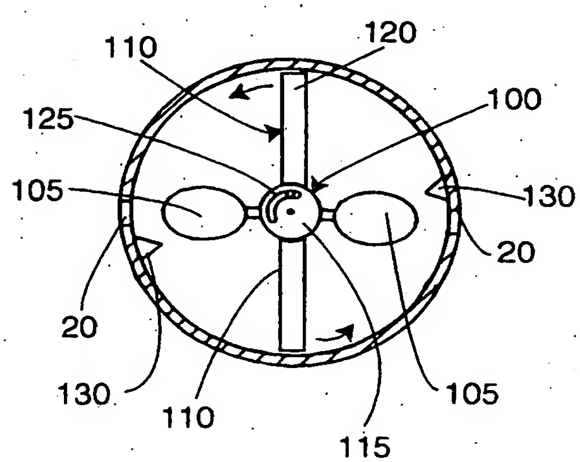

Fig. 13b

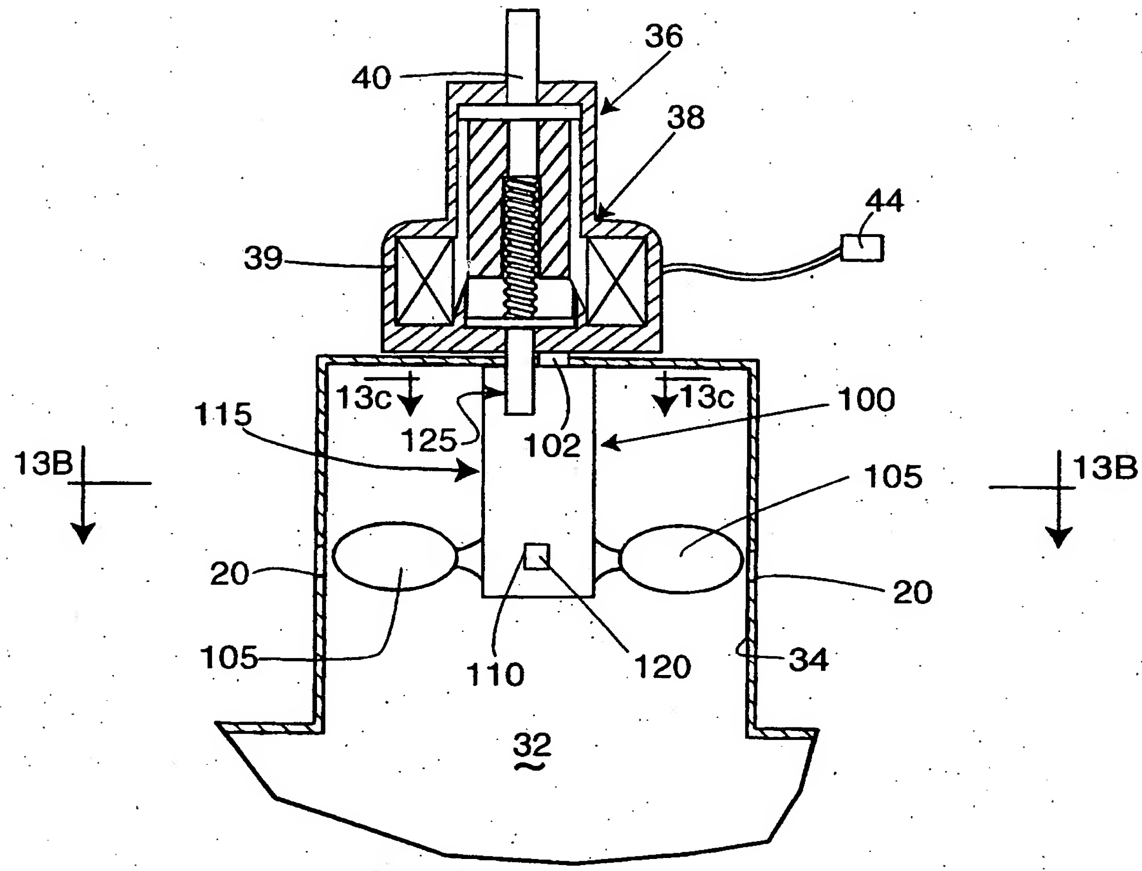

Fig. 13a

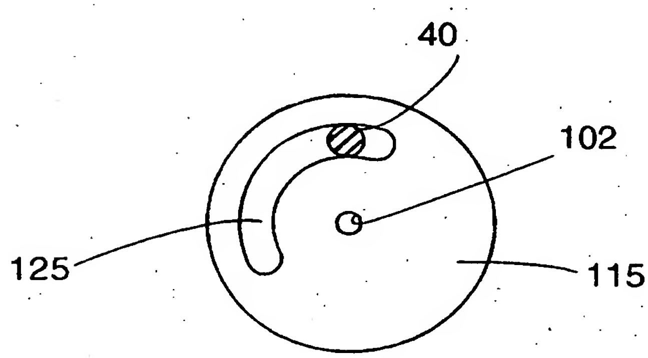

Fig. 13c

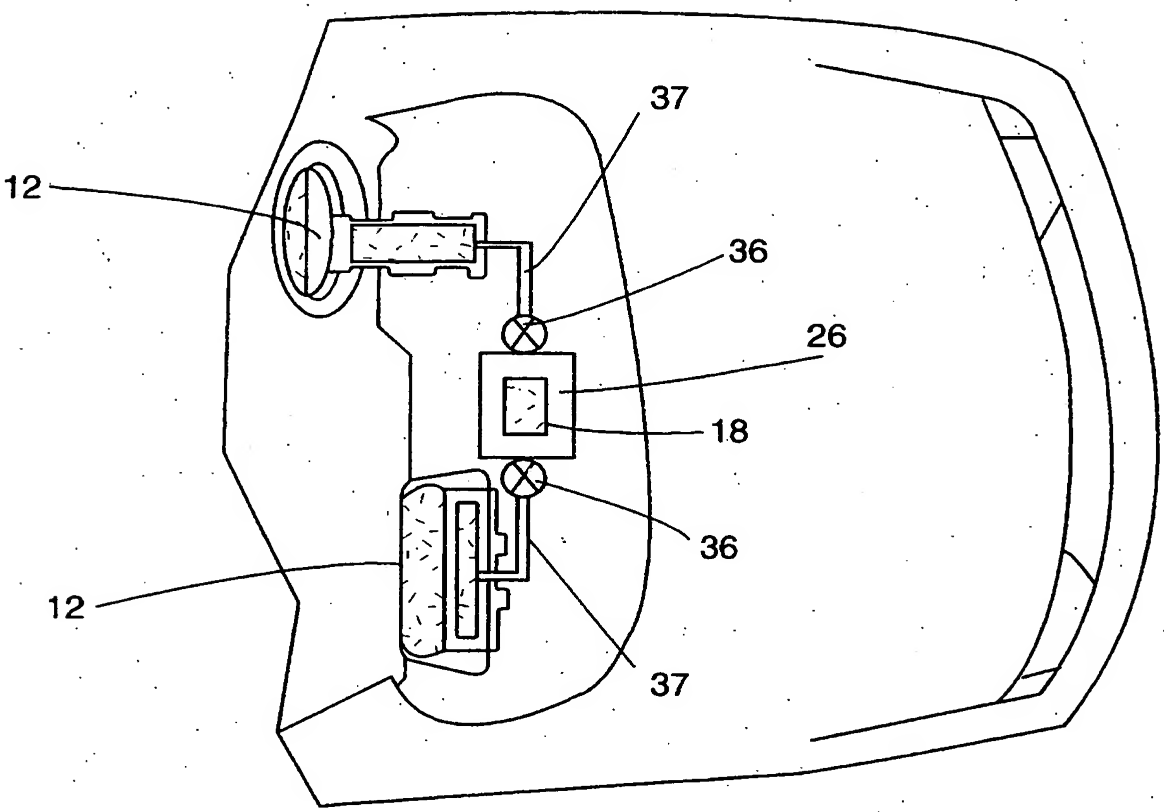

Fig. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/00456

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B60R 21/26, 21/30, 21/28
US CL :280/ 736, 739, 740, 741, 742
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 280/ 736, 739, 740, 741, 742

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search terms: airbag, valve, ring, rotate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,707,078 (SWANBERG et al) 13 January 1998, Figure 1, col. 3, lines 20-35.	1, 2, 4, 5, 6, 7, 10
X --- Y	US 5,618,057 (JOHNSON et al) 8 April 1997, Figures 1-2.	1 ---- 2-4, 8-10
Y	US 5,709,405 (SADERHOLM et al) 20 January 1998, Figures 1-2, col. 4, lines 50-57.	2-4, 10
Y	US 5,639,117 (MANDZY et al) 17 June 1997, Figure 1.	8, 9
A	US 5,700,030 (GOETZ) 23 December 1997, Figures 3-4.	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 FEBRUARY 1999	23 MAR 1999

Name and mailing address of the ISA/US	Authorized officer
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